

or less the proper rhythmic movement necessary to the production of a musical note, according as the intensity of the agitation of effervescence is greater or less.

The dead sound of a cracked glass is probably owing to a similar cause. For in that case, as soon as the vibrations travelling round the glass arrive at the crack, the edges of which are wholly or partially in contact, they are transmitted from edge to edge, and as, owing to the friction of the edges one against the other, their vibrations do not synchronise, a reflex wave is impinged upon each, having a less velocity than the original wave. This reflex wave will correspond to the vibrations caused by effervescence. If the crack be cleanly cut out, so as to separate the edges by a well-defined interval, the glass will again emit a musical note. In the latter case, the sonorous vibrations, on arriving at the cut portion, return by the way they came, synchronising with those which they meet.

The dead sound of the glass, when filled with honey or treacle, is probably owing to the circumstance of these fluids being not sufficiently mobile to vibrate in unison with the glass; and thus they destroy its musical tone as effectually as if they generated an independent and non-synchronous vibration.

London, July 4

ALLEN BEAZELEY

The Names Cambrian and Silurian in Geology

WILL you allow me to express, as an humble worker among the rocks of North Wales, my sense of the high value of the contributions to your pages recently by Prof. Sterry Hunt on the "History of the names Cambrian and Silurian in Geology?" I have long felt—and have not hesitated to express my feeling—that a great wrong was done to Prof. Sedgwick when the North Wales groups of rocks from the Bala Beds to the Lingula Flags—the order of which he was the first to unravel in that difficult region—were unceremoniously engulfed in Siluria.

It has also appeared to me one of the greatest anomalies in English geological classification, that the magnificent and well-defined groups of North Wales should be typified by their attenuated and broken easterly outcrops in the Silurian district of South Shropshire. What Llandeilo section of Siluria is there that worthily represents the Arenig and lower Bala rocks immediately east or west of the Berwyn Mountains? What Caradoc section of Siluria is there at all worthy of the fine series of the Upper Bala rocks of Glyn Cefriog? Of the unworthiness of the schists near the Stiper stones to represent the Lingula beds of North Wales, Prof. Hunt justly speaks in his papers.

I am glad that justice seems at last likely to be done to the veteran, Prof. Sedgwick, than whom a more philosophical geologist I am persuaded does not exist. Let but a sufficient number of scientific men resolve to use his older and truer, because more natural classification, and the justice will soon be complete.

D. C. DAVIES

ON THE VARIATION OF SPECIES AS RELATED TO THEIR GEOGRAPHICAL DISTRIBUTION, ILLUSTRATED BY THE ACHATINELLINÆ

IT has long been known that island species are usually different from, but allied to, those of the neighbouring continents. Darwin has also made us familiar with the fact that each of the Galapagos Islands has a fauna, and to some extent a flora, of its own. Other explorers have called attention to the somewhat limited distribution of species in the West Indies and on other islands. I have been informed by Mr. T. Bland, who has given special attention to the terrestrial molluscs of the West Indies, that if Cuba should be divided into two islands by the submerging of the central portion, about half of the species on either of these islands would be different from those on the other. Some of the most remarkable facts of this kind appear in the distribution of the Achatinellinæ on the Sandwich Islands. As they have never been fully recorded, I make the following brief statement of the leading facts, gathered from the results of personal exploration, and suggest a few inquiries.

Many types of the Sandwich Island Helicidæ have at different times been classed under the generic name of

Achatinella. These widely differing forms have, in the structure of the shell, one point of correspondence that holds them together. The columella has a spiral twist which is more or less apparent in all. In most of the species this character is so strongly developed that the columella seems to be armed with a lamellated tooth revolving within the shell. This common characteristic, in connection with the fact that they are all confined within the limits of one small geographical area, affords sufficient reason for regarding even the most divergent of these types as belonging to one group. As the humming birds are peculiar to America, so the Achatinellinæ are peculiar to the Sandwich Islands.

Though the forms thus brought together evidently constitute a natural group, it has long been apparent that they should be classed under more than one generic name. Some of these genera are restricted to one or two islands.

Genera on Kauai

Several large turreted species of a peculiar type, found only on the island of Kauai, had been provided for at different times under the names of *Achatina*, *Achatinella*, and *Spiraxis*; but no resting-place was found for them till shelter was provided under the separate name of *Carelia*, given by H. and A. Adams. *Carelia turricula*, a species which is sometimes three inches in length and about an inch in diameter, may stand as the representative of this genus. Besides the six or eight species of *Carelia* which have been described, there are many other species of land shells peculiar to this island, the most northern and western of the group. Some of these are *Helices*; the others belong to *Amastra* (H. and A. Adams) and *Leptachatina* (Gould), two genera which are also represented on the other islands of the group. None of the species of this island present any of the brilliant colours that are so common in the shells of Oahu. The peculiar forms of some of the species, as of *Amastra kauaiensis* and *Carelia cumingiana*, as well as the relations of these aberrant types to the types found on the other islands, render them objects of great interest.

Genera on Oahu

On the island of Oahu, which lies next to Kauai on the south-east, we find a remarkable development of the Helicidæ. The ground species belong to the two genera just mentioned, *Amastra* and *Leptachatina*. *A. ventulus* is an example of the former, and *L. vitrea* of the latter. Over twenty-five species of each have been found on this island. Two arboreal genera—the *Bulimella* (Pfeiffer) and *Helicterella* (Gulick)—are found only on this island. The ellipsoidal form, as in *B. rosea*, characterises the former; and the conical form, as in *H. apiculata*, the latter. Of *Bulimella* there are about thirty known species; of *Helicterella* thirty-five. The different species of *Bulimella* present a great variety of colours, ranging from bright green and rose, through yellow, brown, and ash, to simple black and white. The prevailing colours of the *Helicterella* are white, black, and brown, variously arranged in bands and stripes. The arboreal genus *Achatinella* (Swainson) may also be regarded as belonging especially to Oahu, as it is here represented by fifty-four species, and elsewhere by but three, which are found only on the island of Molokai, about fifteen miles to the east. *Achatinella producta*, about one inch in length, is one of the largest of the family. The *Auriculella* (Pfeiffer) is a genus of small arboreal species found on Oahu, and also on the islands to the east. Many of them are unnamed; but those on Oahu probably number more than ten. *Auriculella auricula* is given by Pfeiffer as the type. Two other arboreal genera—*Partulina* (Pfeiffer) and *Laminella* (Pfeiffer)—which find their chief development on the islands of Maui, Molokai, and Lanai, are represented on this island by three species each. The types, as given by Pfeiffer, are *Partulina virgulata*, found on Molokai, and *Laminella gravis*, on Oahu.

Number of Species and Varieties on Oahu, and the Regions they Inhabit

The number of species of Achatinellinæ on Oahu may be estimated at about 185, representing eight genera, but belonging chiefly to five. Besides these there are many small *Helices*, which would probably bring the whole number of the species of Helicidæ on Oahu up to about 200, the varieties numbering 800 or 900. None of these species—excepting, perhaps, one or two of the ground species, which are reported to have been found on the island of Maui—exist anywhere beyond the narrow circuit of this island, the extreme length of which is only 60 miles, with an average breadth of about 15 miles. Nor does any one species occupy a large proportion of even this area. Nearly all are confined to the forest regions skirting two ranges of mountains. The chief range, on the north-east side of the island, is about 40 miles in length. The forest region that covers it has an average breadth of five or six miles. The range on the opposite side of the island is about half as long, and has only about one-fourth as much forest land. The north-eastern side of the island, owing to its receiving the trade-winds when they first strike the island, enjoys a moister climate and possesses more luxuriant vegetation than the south-western side. We are therefore somewhat prepared to find that seven-eighths of the species, or about 175, are found in the former area, about 40 miles in length and five or six miles in width. Passing over innumerable minor variations, the varieties found in this area are no less than 700 or 800.

That so large a number of species and varieties of land molluscs should be found within so small an area is, I think, unparalleled in the records of conchology; but that this great number of forms should, with but two or three exceptions, be found nowhere beyond these narrow limits, not even on the other half of the same island, is still more astonishing. What shall we say when we discover that no one of these species is distributed over even half of this small mountain range; but that in most cases they are restricted to areas of from one to five miles in length? Have we found one of the "centres of creation"?

The principal facts in the geographical distribution of these forms are as follows:—

I.—Facts relating to the Position and Natural Divisions of the Territory

The Sandwich Islands are surrounded by a wider expanse of open ocean than any other islands of equal extent. The forms of Helicidæ on this group differ widely from those of other lands. Not only do we find distinct species and genera, but a separate group of genera.

The group of islands may be divided into four provinces, each of which has a separate set of species and possesses one genus or more that is peculiar to the province, besides other genera that are common to several provinces. (a) On Kauai alone is found the *Carelia*; (b) on Oahu, the *Bulimella* and *Helicterella*; (c) on Maui, Molokai and Lanai, the *Newcombia* (Pfeiffer); (d) on Hawaii, certain peculiar forms that have not yet been fully collected or classified. Kauai, which is separated from the other islands by the widest channel, has the forms that differ the most widely from those of the central part of the group.

Most of the species are confined to the forests of mountain regions; and where, as on Oahu and Maui, there are two regions of forest divided by several miles of grass country, the island is also divided into two sections, having but few, if any, species in common.

On the island of Oahu, the two sections which occupy separate mountain ranges are divided into many minor sections in the following manner. From each side of the main range project mountain ridges, which separate deep valleys a mile or two in width. Each of these valleys is a subordinate section, having its own varieties and in many instances its own species, which are found nowhere else.

II.—Facts relating to the Variation and Affinity of Species

Nearly all the species of one genus found on one mountain range are connected by varieties presenting very minute gradations of form and colour. Species of the same genus on different islands are not so completely connected by intermediate forms.

The degree of difference between several species of the same group is in proportion to their separation in space.

Nearly allied species, occupying neighbouring localities, pass into each other by all the intermediate gradations of form and colour, while those whose homes are separated by a distance of eight or ten miles, cannot be connected by minute gradations without bringing in some of the forms occupying the intermediate territory.

As the relations to each other of the valleys surrounding any mountain are determined by the shape of the mountain with its ridges, so are the relations of these species to each other, in the arrangement of their affinities and divergences, influenced by the same cause. As the geometrical relations to each other of valleys clustered around one central peak differ from those distributed on either side of a long range, so do the affinities and divergences (the structural relations to each other) of the species on one of the high solitary mountains of Maui differ from those on one of the mountain ranges of Oahu. On the eastern range of Oahu the species of *Achatinella* are distributed on both sides of the mountain in parallel lines, the extremes of divergence being in the forms at the ends of the range. But either on East Maui or West Maui, where the arrangement of the valleys is more concentric, the varieties of any one group of species converge so rapidly toward one central type, that it is difficult to distribute them into well-defined species.

III.—Facts relating to the comparative Area occupied by Species of different Classes

The average length of the area occupied by different species is perhaps five miles.

Field species have the widest range. Arboreal species have the narrowest range. Ground species found in forest regions have a medium range.

Many interesting questions are suggested by these facts. How can we account for the species being restricted in their distribution to such narrow limits? Why do not the species of North-eastern Oahu pass over their narrow bounds and become mingled throughout the whole extent of that short mountain range?

Questions Suggested

The minute gradations by which the species of each genus of the Achatinellinæ are connected with each other strongly favours the belief that many of them must have been derived the one from the other by successive variations. If created independently, why should there be such gradation? Why should the species of one group be so arranged that those intermediate in form are found in intermediate localities? It may be said that those of one group, which are gradated together by intermediate varieties, are not only from one stock, but are one species. If they are one species, how shall we account for the difference of size and form, the entire change of colour, and in many instances of habits, leading some of the so-called varieties to avoid plants that are chosen by other varieties living only a few miles distant, and to choose plants that are rejected by the others? Why should the *Achatinella* feed on Kukui trees (*Aleurites triloba*) in the eastern districts of the island, and in the north-western choose small shrubs, leaving the Kukui trees to the *Bulimella*? Whether we call the different forms species or varieties, the same questions are suggested, as to how they have arisen, and how they have been distributed in their several localities.

In attempting to answer these questions, we find it difficult to point to any of those active causes of accumulated variation, classed by Darwin as illustrations of

"Natural Selection." The conditions under which they live are so completely similar, that it does not appear what ground there can be for difference in the characters best fitting the possessors for survival in the different valleys in which they are found. The vegetation is much the same; the bird and insect enemies, so far as they have any, are the same. The north-east side of the mountain range is a little more rainy than the opposite side, but this does not account for the different forms found in the successive valleys on the same side of the range. In what respect can the conditions of survival to which *Achatinella stewarti* is subjected in Manoa, differ from those under which *A. producta* lives in Makiki, only a mile distant, or from those in which *A. varia* is placed in Palolo, three miles away? There is no reason to doubt that some varieties less fitted to survive have disappeared; but it does not follow that the "Survival of the Fittest"—(those best fitted when compared with those dying prematurely, but equally fitted when compared with each other)—is the determining cause which has led to these three species being separated from each other in adjoining valleys. The "Survival of the Fittest" still leaves a problem concerning the distribution of those equally fitted. It cannot be shown that the "Survival of the Fittest" is at variance with the survival, under one set of external circumstances, of varieties differing more and more widely from each other in each successive generation. The case of the three species under consideration does not seem to be one in which difference of "Environment" has been the occasion of different forms preserved in the different localities. It is rather one in which varieties resulting from some other cause, though equally fitted to survive in each of the three localities, have been distributed according to their affinities in separate localities. There is no reason to think that *A. producta* is not as well fitted to live on the Kukui trees that abound in Manoa and Pololo, as on the same trees in Makiki. Again, is the "Survival of the Fittest" sufficient to explain their being kept within these extremely narrow limits since they were produced? One would at first suppose that, in the course of a few years, or in a few hundred years at the farthest, the three species would have been diffused throughout this area of only five or six square miles which is now divided between them.

We seek in vain for an explanation of these facts in the still further principle of variation, set forth by Herbert Spencer under the effects of change in use, and discussed by Prof. Cope under the names of "Acceleration and Retardation." This cause of accelerated variation has influence only where there is a difference in the "use, either compulsory or optional." If, on the one hand, the change is compulsory, it must be owing to a change in external circumstances. But in the case of these three species we are unable to find any difference in their circumstances requiring change. Their enemies are the same, the climate is the same, and they undoubtedly eat the same food, for the chief resort of all is the Kukui tree. If, on the other hand, the change in the use is optional, and without reference to change in circumstances, it belongs to the class of spontaneous variations, and does not explain why those of one type of variation (or of one kind of choice) should be brought together and limited to so small an area.

Relations of the Genera

The relations of the genera of Achatinellinae involve problems of still greater interest, but more difficult to penetrate. The limits of this paper render it impossible to do more than to give some of the most striking facts, and indicate some of the questions that arise.

Through the varieties of *A. oviformis* and *B. Sowerbyana*, the genus *Achatinella* passes by minute gradations into *Bulimella*; but connections of this kind have not been noted between the other genera.

The family is divided into two natural groups of genera.

The first group consists of seven genera: *Achatinella*, *Bulimella*, *Heliciterella*, *Partulina*, *Newcombia*, *Laminella*, and *Auriculella*. These are all arboreal in their habits. In form they are either sinistral, or both dextral and sinistral. The second group consists of three genera: *Amastrea*, *Leptachatina*, and *Carelia*. With but few exceptions, the species of *Amastrea* and *Leptachatina* live on the ground and are of dextral form. I am not informed concerning the habits of *Carelia*, but the structure of the shell and its invariably dextral form show that it belongs to this group.

Of the second group, *Carelia* is found on Kauai, the most western of the Sandwich Islands. The two remaining genera are found on all the islands. The first, or arboreal group, is represented on all the islands except Kauai. The separate genera are more restricted in their distribution. Two are found only on Oahu, a third on Oahu and Molokai, a fourth on Molokai and Maui, and the remaining two on several islands.

The genus *Helix* is represented on all the islands. So far as I know, the species all live on the ground, and are all dextral in form. They are all small in size, with spire very much depressed, and have no trace of the peculiar twist in the columella which characterises the Achatinellinae.

Why should nearly all the ground species be dextral, and many, if not a majority, of the arboreal species be sinistral? Does this fact point to one common origin for the arboreal genera, and a separate origin for the ground genera? Or are we to suppose that arboreal habits tend to produce sinistral forms? The few species of *Amastrea* which are found on trees retain the dextral form that belongs to the allied species living on the ground.

Facilities needed for the Study of Variation of Species

I am fully persuaded that the study of allied forms in their geographical relations is one of the richest fields open to the naturalist. He may here reap a harvest of facts throwing light on many of the questions that are now occupying the special attention of the scientific world.

To afford suitable opportunity for such studies, it is necessary that certain sections of our museums should be devoted to the exhibition of objects in an arrangement more strictly geographical than anything that has yet been attempted. The leading feature in the arrangement adopted by Agassiz in the museum at Cambridge, Massachusetts, is the geographical grouping of objects; but for the fuller presentation of the curious facts of geographical distribution, it is further needed that in certain wisely chosen families the objects should be laid down in their actual geographical relations, as on a map. It is not necessary that the map on which they are arranged should be as mathematically correct as a nautical chart. It will be sufficient if cases are prepared, approximately representing the territory or territories chosen, with subdivisions representing the different localities in which the specimens have been found.

Collections for such a purpose should be made with scrupulous care. The locality of every object should be noted with great minuteness. In collecting shells at the Sandwich Islands, noting the name of the island is not sufficient, nor yet the name of the district. Each valley, with its area two or three miles in length, and but one or two miles in width, needs to be separately explored, and all the shells labelled with the name of the valley. To show the relations of the species to each other, as complete a series as possible should be obtained of the countless varieties.

For this kind of study the fauna of the Sandwich Islands is of peculiar interest, on account of the number of forms, and the variety of relations presented within a small compass.

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